CLAIMS

1. A projection optical system which projects a reduced image of a pattern illuminated with light onto a substrate through liquid, the projection optical system comprising:

a first optical system which forms a first intermediate image of the pattern with the light, the first optical system including first lenses;

a second optical system which forms a second intermediate image of the pattern with the light from the first optical system, the second optical system including a plurality of mirrors; and

a third optical system which forms the reduced image of the pattern with the light from the second optical system, the third optical system including second lenses,

wherein the second optical system includes no transmissive member,

wherein an optical axis each optical element of the first, second and third optical system is substantially arranged on a single optical axis,

wherein the plurality of mirrors comprises at least two concave mirrors,

wherein the at least two concave mirrors comprises:

a first concave mirror of which reflection surface is arranged toward to a first surface on which the pattern is arranged, and which reflects the light from the first optical system; and

a second concave mirror of which reflection surface is arranged toward to a second surface on which the substrate is arranged, and which reflects the light from the first concave mirror,

wherein the first concave mirror is arranged so that an area on the reflection surface of the first concave mirror, into which the light from the first optical system enters, does not cross the single optical axis, and

wherein an exit pupil of the projection optical system has no shield area.

2. The projection optical system according to Claim 1, wherein the second concave mirror is arranged so that an area on the reflection surface of the second concave mirror, into which the light from the first concave mirror enters, does not cross the single optical axis.

3. The projection optical system according to Claim 1, wherein the third optical system comprises an aperture stop, and the second lenses of the third optical system includes a plurality of negative lenses arranged in an optical path of the light on an incidence side of the aperture stop.

4. The projection optical system according to Claim 3, wherein a first negative lens of the plurality of negative lenses, of which diameter to transmit the light is the smallest in the plurality of negative lenses, is a biconcave lens.

5. The projection optical system according to Claim 4, wherein the second lenses of the third optical system comprises at least three lenses arranged in the optical path between the first negative lens and the aperture stop.

6. The projection optical system according to Claim 5, wherein the at least three lenses comprise at least three positive lenses.

7. The projection optical system according to Claim 6, wherein the at least three positive lenses comprise at least one positive meniscus lens.

8. The projection optical system according to Claim 6, wherein the at least three positive lenses comprise at least two biconvex lenses.

9. The projection optical system according to Claim 4, wherein the plurality of negative-lenses comprises a second negative lens arranged in the optical path on an incidence side of the first negative lens and arranged adjacent to the first negative lens.

10. The projection optical system according to Claim 9, wherein the second negative lens is a negative meniscus lens.

11. The projection optical system according to Claim 9, wherein a distance on the single optical axis between the first negative lens and the second negative lens is shorter than that between the first negative lens and the aperture stop.

12. The projection optical system according to Claim 1, wherein the first lenses of the first optical system comprises at least three lenses.

13. The projection optical system according to Claim 12, wherein the at least three lenses comprise three convex lenses.

14. The projection optical system according to Claim 1, wherein the third optical system forms the reduced image in an area away from the single optical axis.

15. An exposure apparatus which exposes a substrate through liquid with light from a pattern on a mask, the exposure apparatus comprising;

a stage which supports the substrate; and

the projection optical system according to Claim 1, which projects a reduced image of the pattern with the light onto the substrate supported by the stage through the liquid below the projection optical system.

16. The exposure apparatus according to Claim 15, further comprising an illumination optical system which illuminates the pattern with s-polarized light.

17. The exposure apparatus according to Claim 15, further comprising a liquid supplying device which supplies the liquid in an optical path of the light between the projection optical system and the substrate supported by the stage.

18. An exposure method for exposing a substrate through liquid with light from a pattern on a mask, the exposure method comprising:

supporting the substrate by a stage; and

projecting a reduced image of the pattern with the light onto the substrate supported by the stage through liquid by using the projection optical system according to Claim 1.

19. The exposure method according to Claim 18, further comprising:

illuminating the pattern with s-polarized light.

20. The exposure method according to Claim 18, further comprising:

supplying the liquid in an optical path of the light between the projection optical system and the substrate supported by the stage.

21. A method of manufacturing a device, comprising:

exposing a substrate with light from a pattern on the mask through liquid by using the projection optical system according to Claim 1; and

developing the substrate exposed with the light.

22. A projection optical system which projects a reduced image of a pattern illuminated with light onto a substrate through liquid, the projection optical system comprising:

a first optical system which forms a first intermediate image of the pattern with the light, the first optical system including first lenses;

a second optical system which forms a second intermediate image of the pattern with the light from the first optical system, the second optical system including a plurality of mirrors; and

a third optical system which forms the reduced image of the pattern with the light from the second optical system, the third optical system including second lenses,

wherein the second optical system includes no transmissive member,

wherein an optical axis of each optical element of the first, second and third optical system is substantially arranged on a single optical axis,

wherein the plurality of mirrors comprises at least two concave mirrors,

wherein the at least two concave mirrors comprises:

a first concave mirror of which reflection surface is arranged toward to a first surface on which the pattern is arranged, and which reflects the light from the first optical system; and

a second concave mirror of which reflection surface is arranged toward to a second surface on which the substrate is arranged, and which reflects the light from the first concave mirror,

wherein the second concave mirror is arranged so that an area on the reflection surface of the second concave mirror, into which the light from the first concave mirror enters, does not cross the single optical axis, and

wherein an exit pupil of the projection optical system has no shield area.

23. An exposure apparatus which exposes a substrate through liquid with light from a pattern on a mask, the exposure apparatus comprising;

a stage which supports the substrate; and

the projection optical system according to Claim 22, which projects a reduced image of the pattern with the light onto the substrate supported by the stage through the liquid below the projection optical system.

24. The exposure apparatus according to Claim 23, further comprising an illumination optical system which illuminates the pattern with s-polarized light.

25. The exposure apparatus according to Claim 23, further comprising a liquid supplying device which supplies the liquid in an optical path of the light between the projection optical system and the substrate supported by the stage.

26. An exposure method for exposing a substrate through liquid with light from a pattern on a mask, the exposure method comprising:

supporting the substrate by a stage; and

projecting a reduced image of the pattern with the light onto the substrate supported by the stage through liquid by using the projection optical system according to Claim 22.

27. A projection optical system which projects a reduced image of a pattern illuminated with light onto a substrate through liquid, the projection optical system comprising:

a first optical system which forms a first intermediate image of the pattern with the light, the first optical system including first lenses;

a second optical system which forms a second intermediate image of the pattern with the light from the first optical system, the second optical system including a plurality of mirrors; and

a third optical system which forms the reduced image of the pattern with the light from the second optical system, the third optical system including second lenses,

wherein the second optical system includes no transmissive member,

wherein an optical axis of each optical element of the first, second and third optical system is substantially arranged on a single optical axis,

wherein the plurality of mirrors comprises a reflecting mirror including a reflecting area to reflect the light from the first intermediate image, the reflecting area being arranged so as not to cross the single optical axis, and

wherein an exit pupil of the projection optical system has no shield area.

28. The projection optical system according to Claim 27, wherein the reflecting mirror comprises a first concave mirror and a second concave mirror, the second concave mirror including the reflecting area and being arranged on an exit side of the first concave mirror along an optical path of the light from the first intermediate image.

29. The projection optical system according to Claim 28, wherein the second concave mirror is arranged nearest to a plane on which the pattern is placed, among the plurality of mirrors.

30. The projection optical system according to Claim 27, wherein the reflecting mirror includes a first concave mirror of which the reflecting surface is arranged so as to face to a plane on which the pattern is placed and a second concave mirror of which the reflecting surface is arranged so as to face to a plane on which the pattern is placed.

31. An exposure apparatus which exposes a substrate through liquid with light from a pattern on a mask, the exposure apparatus comprising;

a stage which supports the substrate; and

the projection optical system according to Claim 27, which projects a reduced image of the pattern with the light onto the substrate supported by the stage through the liquid below the projection optical system.

32. The exposure apparatus according to Claim 31, further comprising an illumination optical system which illuminates the pattern with s-polarized light.

33. The exposure apparatus according to Claim 31, further comprising a liquid supplying device which supplies the liquid in an optical path of the light between the projection optical system and the substrate supported by the stage.

34. The exposure apparatus according to Claim 31, wherein the reflecting mirror comprises a first concave mirror and a second concave mirror, the second concave mirror including the reflecting area and being arranged on an exit side of the first concave mirror along an optical path of the light from the first intermediate image.

35. The exposure apparatus according to Claim 34, wherein the second concave mirror is arranged nearest to a plane on which the pattern is placed, among the plurality of mirrors.

36. The exposure apparatus according to Claim 31, wherein the reflecting mirror includes a first concave mirror of which the reflecting surface is arranged so as to face to a plane on which the pattern is placed and a second concave mirror of which the reflecting surface is arranged so as to face to a plane on which the pattern is placed.

37. An exposure method for exposing a substrate through liquid with light from a pattern on a mask, the exposure method comprising:

supporting the substrate by a stage; and

projecting a reduced image of the pattern with the light onto the substrate supported by the stage through liquid by using the projection optical system according to Claim 27.